Effects of a Clearcut on the Herpetofauna of a South Carolina Bottomland Swamp

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ABSTRACT—Amphibians and reptiles were trapped during summer in a South Carolina bottomland swamp to assess the impacts of clearcut timber harvesting. Animals were captured using drift fences with pitfall traps, coverboards, and polyvinyl chloride pipes which simulated treefrog habitat. Twenty-nine species (10 amphibians and 19 reptiles) were detected on the site. Some were captured frequently enough to infer microhabitat preferences. Salamanders were much more frequent in the control area than in the clearcut. Other species showing preferences for the control were bronze frogs (*Rana clamitans*), gray treefrogs (*Hyla chrysoscelis*), and box turtles (*Terrapene carolina*). Reptiles generally preferred the clearcut. This was especially true of lizards and large snakes. Diversities showed no significant differences between the control and clearcut. Small clearcuts done on long rotations are recommended. Machinery impact should be kept to a minimum, and down wood and snags should be left on the site.

Bottomland hardwood forests have been recognized for their importance in floodwater and sediment retention, water quality protection, timber production, and wildlife habitat (Brinson et al. 1981, Clark and Benforado 1981, Harris and Gosselink 1986). At the same time, these ecosystems are being lost and degraded rapidly (Turner et al. 1981, Rudis 1993) due in large part to fragmentation. In the Southeast, 75,000 acres of forested wetlands have been lost since 1982 (Cubbage and Flather 1993), not including acreage that was logged and regenerated. These logged wetlands may temporarily lose some functional value, and they contribute to fragmentation.

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The research results presented here were obtained concurrent with other studies (Pavel 1993, Perison In Press) designed to document the impact of timber harvesting on the functional value of a bottomland swamp. Amphibians and reptiles (herpetofauna) were chosen as the appropriate wildlife groups to study because of their abundance in the Southeast (Keister 1971, Vickers et al. 1985, Hairston 1987) and because of their importance in food chains (Pough et al. 1987, Blaustein and Wake 1990). Herpetofaunal species are also influenced by factors that are affected by timber harvest, including hydrology, soil quality, and vegetative structure. Herpetofaunal communities have been shown to be altered by clearcutting (Enge and Marion 1986, Pough et al. 1987, Petranka et al. 1993), ditching of wetlands (Vickers et al. 1985, Enge and Marion 1986), and changing forest cover (Bennett et al. 1980, Pough et al. 1987).

In addition, much attention has been paid to a possible worldwide decline in amphibian diversity (Blaustein and Wake 1990, Pechmann et al. 1991, Hairston and Wiley 1993). Logging has been identified among the many possible causes of such a decline (Wake 1991, Hairston and Wiley 1993). Amphibians may be a good indicator of general environmental degradation, due to their exposure to terrestrial and aquatic toxins, and their sensitivity to habitat changes (Beiswenger 1988, Blaustein and Wake 1990).

The objectives of our research were to evaluate whether clearcutting in a hardwood swamp had any effect on community diversity or abundance of summer-active amphibians and reptiles. We also attempted to identify habitat variables that may have been related to changes in the herpetofaunal community.

METHODS

Study Site

The study site was on the South Fork of the Edisto River, near Norway (Orangeburg County), South Carolina. "The site is representative of blackwater swamps in the Carolinas that have timber management potential" (Perison et al. 1993). Predominant trees in the swamp forest included tupelo gum (*Nyssa* spp.), sweetgum (*Liquidambar styraciflua*), willow/water oak (*Quercus phellos/nigra*), and green ash (*Fraxinus pennsylvanica*) (Pavel 1993). A clearcut of approximately 10 ha was completed in January 1991. Much of the clearcut area was impacted by skidder tire ruts. The adjacent control area was upstream of the clearcut and was a second growth stand approximately 45 years old. Second growth forest surrounded the clearcut. The sampled area of control was comparable to the size of the clearcut. The edge sampled was 650 m long.

HERPETOFAUNA

Sampling—Amphibians and reptiles were captured using three types of traps: drift fences, coverboards, and polyvinyl chloride (PVC) pipe. Nine arrays of drift fences, measuring 270 m in total, were constructed of aluminum flashing (Gibbons and Semlitsch 1981). Each array consisted of two 15-m lengths placed at right angles to one another. Three of the arrays were placed in the clearcut, three in the control, and three along the edge between the clearcut and control. Twelve pitfall traps (19–L plastic paint buckets) were placed along each array, for a total of 108 traps. Arrays were centered in the clearcut, about 75 m from the edge. Control arrays averaged about 75 m from the edge.

Forty-five coverboards were systematically placed across the study site, 30 in the clearcut and 15 in the control. Each coverboard consisted of a piece of plywood or particle-board (about 120 x 60 x 0.625 cm) placed flat on the ground to simulate the type of cover often used by ground-dwelling herpetofauna (DeGraff and Yamasaki 1992, Fitch 1992, Mitchell et al. 1993). Coverboards were placed a minimum of 20 m apart.

Sixty 1.5-m lengths of PVC pipe were driven into the soil to capture treefrogs. The diameters of the pipes were 2.5 and 5 cm. Forty pipes were used in the clearcut, and 20 in the control. These pipes served as refuges for treefrogs, which were easily captured at the open top ends of the pipes. One nocturnal chorus survey (July 1993) was done to compare to habitat use trends indicated by the pipe captures. Frog choruses were monitored from the clearcut, control, and edge for 30 minutes each. Weather was humid, warm, clear, and calm.

Each of the traps was checked daily during the summers of 1992 and 1993. All captured animals were released immediately. Adult anurans were toe-clipped, but no capture-recapture data will be presented here (see below). In 1992, we trapped from 29 May until 13 August, with the exception of 14 days when the swamp was flooded. On those days, only the treefrog pipes were checked. In 1993, four drift fence arrays (one control, two edge, one clearcut) were checked from 20 May to 12 August. The remaining traps were checked from 20 June to 12 August. Again, sampling was impeded due to flooding.

Sampling was replicated within the control, edge, and clearcut site, but not replicated with additional sites because of constraints imposed by the establishment of concurrent studies, which used small replicated treatment blocks within the clearcut (Pavel 1993, Phelps 1993, Perison In Press). These blocks were the reason for unequal sampling effort for coverboards and PVC pipes in the clearcut, edge, and control. Due to the lack of replication, the results and conclusions from this study apply to the particular site we studied. Generalization to other sites is risky.

Data analysis—Capture data were analyzed using the Shannon-Weaver Diversity Index (Poole 1974). This allowed statistical comparisons among drift fence arrays in the clearcut, on the edge, and in the control; and between coverboards in the clearcut and in the control. Variance for each treatment was calculated based on the number of captures in each treatment, and was used to calculate the *t*-statistic (α = 0.05) for each comparison (Poole 1974). The formulas used are as follows:

$$H' = \Sigma_{i=1}^{s} p_i \ln p_i$$

$$\mathrm{Var}(H') = \frac{[\Sigma_{i=1}^{s} p_i \ln^2 p_i] - [\Sigma_{i=1}^{s} p_i \ln p_i]^2}{N} + \frac{s-1}{2N^2}$$

$$t = \frac{H'_1 - H'_2}{[\mathrm{Var}(H'_1) + \mathrm{Var}(H'_2)]^{1/2}}$$

$$\text{d.f.} = \frac{[\mathrm{Var}(H'_1) + \mathrm{Var}(H'_2)]^2}{\frac{[\mathrm{Var}(H'_1)]^2}{N_1} + \frac{[\mathrm{Var}(H'_2)]^2}{N_2}},$$

where i represents each species in the sample, pi = proportion of species i in the sample, s = number of species in the sample, N = number of captures in the sample.

Assumptions of the Shannon-Weaver Index were that all species present were sampled, and all were equally catchable. These assumptions were not met because of the differing ability of the traps to catch various species (Gibbons and Semlitsch 1981). Also, two species caught by hand were never captured in a trap of any kind and were therefore excluded from calculations of H'. These were the brown water snake (*Nerodia taxispilota*) and the timber rattlesnake (*Crotalus horridus*). Their size explains the lack of pitfall captures, as no larger snakes were caught in pitfalls. Other large snakes were captured under coverboards.

Poole (1974) states that "no great error" will occur in calculating Shannon-Weaver as if all the species available are present in the sample, even when, as in this case, some species are not represented. Unequal catchability of species should still allow relative diversity comparisons.

The lack of replication allowed only a rough comparison of capture frequencies, not a statistical test of differences in abundance (Hurlbert 1984). The original intent was to estimate abundances of anurans using mark-recapture methods, but a lack of sufficient recapture prevented this. To make direct comparisons of capture frequencies, we assumed that capture probabilities for each species were the same across habitats. This assumption could not be tested, so habitat preferences should be interpreted with caution.

Habitat Characteristics

Sampling—In an attempt to relate herpetofaunal diversity to microhabitat variability, the percent cover of midstory and overstory trees was measured with a spherical densiometer at five points around each drift fence array. One reading was taken in the center and one at a distance of 15 m in each cardinal direction. Percent cover of vegetation less than 2 m tall was also measured, using a line intercept method (Barbour et al. 1987). There were four 15-m transects at each drift fence array, originating at the middle of the array and extending in each cardinal direction. A complete description of the vegetation of the site is given by Pavel (1993).

The cross-sectional area of coarse woody debris was measured using the same transects. In this case, the transects were thought of as vertical planes that extended from the ground to the highest piece of downed wood. Each piece of wood greater than 8-cm diameter (at the point of intersection) was measured to the nearest centimeter and classified as "sound" or "rotten" (Brown 1974).

Surface soil temperatures and soil densities were measured by Perison (In Press) in the control and clearcut areas. All habitat data were analyzed using *t*-tests at the 0.05 alpha level. Each measurement was considered to be independent, and means and standard errors were calculated for each variable. In the clearcut, soil temperature and density were measured in areas with skidder traffic, but not in skidder ruts. These variables were not measured at the edge.

RESULTS

Herpetofauna

Shannon-Weaver Diversity Indices calculated for the drift fence and coverboard captures are given in Table 1. There was no significant difference between clearcut and control diversity indices for either of the two trapping methods. The diversity of the edge drift fences was lower than either the control (t = 8.70, d.f. = 1,538) or clearcut drift fences (t = 9.70, d.f. = 2,209). The reason for this difference was the

Table 1. Summary of herpetofauna capture data, Edisto River swamp, South Carolina, 1992–1993. *H′* is the value of the Shannon-Weaver diversity index. Values of *H′* with the same letter were not different at 5% alpha level.

	Captures (*N*)	Species (*s*)	*H′*
Control drift fences	930	16	0.9161a
Clearcut drift fences	1,172	16	0.9109a
Edge drift fences	2,647	17	0.4738b
All drift fences	4,749	23	0.7153c
Control coverboards	150	9	1.7077d
Clearcut coverboards	129	16	1.7710e
All coverboards	279	19	1.9832e

heavy weighting toward one species, the southern toad (*Bufo terrestris*), on the edge. Clearcut and control drift fence diversities were not different at the 0.05 alpha level. Coverboard diversities were higher than drift fence diversities (t = 18.5, d.f. = 333). Drift fences captured more species (23) and individuals (4,749) than coverboards (19 and 279, respectively). The inclusion of the clearcut increased the richness of the capture sample. Twenty-three species were captured on the site in drift fences, but only 16 species were captured in the clearcut, and 16 in the control. Nineteen species were captured under coverboards, but only 16 were captured in the clearcut, and nine in the control.

Several species showed clear preferences for either the control or the clearcut (Table 2). All types of salamanders were detected more often in the control area. A total of 112 salamanders was captured in pitfall traps and under coverboards. Ninety-two (82.1%) of these were captured in the control area, with only 9 (8.0%) in the clearcut (Table 2). Bronze frogs (*Rana clamitans*) were captured more frequently in the control (104 control captures to 17 in the clearcut), while southern leopard frogs (*R. utricularia*) were less common in the control (33 drift fence captures compared to 52 on the edge and 51 in the clearcut). Other frog species showing preferences were eastern narrow-mouth toads (*Gastrophryne carolinensis*) and green treefrogs (*Hyla cinerea*), which preferred the clearcut, and gray treefrogs (*H. chrysoscelis*), which preferred the control. Southern toads, most of which were juveniles, were captured most frequently in the edge pitfalls. Southern toads were abundant in all three areas. The data on frog and toad species were supported by the breeding chorus monitoring.

Reptiles generally seemed to prefer the clearcut. Eastern mud turtles (*Kinosternon subrubrum*) were captured 41 times in the clearcut, 35 times on the edge, and only 10 times in the control area. Common musk turtles (*Sternotherus odoratus*) and eastern box turtles (*Terrapene carolina*) showed the opposite trend. Lizards (*Eumeces fasciatus* and *Anolis carolinensis*) and large snakes (chiefly *Agkistrodon piscivorus* and *Nerodia* spp.) were more common in the clearcut. Because they were rarely captured in traps but often seen, habitat preferences of large snakes, lizards, and box turtles are largely inferred from hand captures, rather than trapping data.

Habitat Characteristics

Microhabitat variables measured in each area are given in Table 3. Over- and mid-story canopy cover was highest in the control (95%), followed by the edge (74%), and clearcut (6%). Understory canopy cover followed the reverse trend, being highest in the clearcut (95%), followed by the edge (48%), and the control (5%).

Cross-sectional area of sound coarse woody debris was significantly higher in the clearcut, and not significantly different between the edge and control. The mount of rotten coarse woody debris was not different among the three areas. Soil surface temperature and soil compaction were not measured on the edge, but were not significantly different between the clearcut and the control, or between rutted and non-rutted areas in the clearcut.

DISCUSSION

Habitat Preferences

Fewer salamanders were captured in the clearcut, as compared to the control. High temperatures and insolation, and low relative humidity may all have contributed to this, as these factors increase the risk of desiccation. Salamanders need to keep their skin moist for gas exchange, and their large surface areas to volume ratios make moisture retention difficult (Duellman and Trueb 1986). Moisture is a key factor in determining where salamanders can live (Wyman 1988, Petranka et al. 1993). Petranka et al. (1993) speculated that 75% to 80% of southern Appalachian salamanders die of physiological stress due to desiccation following clearcuts.

Ecological differences may explain the varying preferences of frog species. Southern toads are generalists, and their common occurrence along the edge suggests that individuals were using both habitats. Bronze frogs and southern leopard frogs showed opposing preferences, for the control and clearcut respectively. Bronze frogs

Table 2. Herpetofauna capture data by species, habitat, and trap type, Edisto River swamp, South Carolina, 1992–1993. Clearcut captures for coverboards and treefrog pipes are halved since they represent twice the sampling effort as in the control. For treefrog pipes, bold numbers are for 5-cm-diameter pipes; others are for 2.5-cm-diameter pipes.

Species	Drift fence captures			Coverboard captures		Treefrog pipe captures	
	Control	Edge	Clearcut	Control	Clearcut	Control	Clearcut
Bufo terrestris	725	2,417	894	29	35	0	0
Gastrophryne carolinensis	42	50	146	0	3.5	0	0
Rana clamitans	86	42	6	18	5.5	0	0
Rana utricularia	33	52	51	6	5	0	0
Hyla cinerea	0	0	0	0	0	**10** 29	**418** 311
Hyla chrysoscelis	0	0	0	0	0	**11** 19	**0** 3
Eurycea quadridigitata	2	7	1	57	2.5	0	0
Eurycea longicauda	3	2	0	2	0	0	0
Desmognathus auriculatus	4	1	1	24	0	0	0
Siren intermedia	0	1	0	0	1	0	0
Terrapene carolina	0	1	2	0	0	0	0
Stemotherus odoratus	10	13	5	0	0.5	0	0
Kinosternon subrubrum	10	35	41	0	0	0	0
Clemmys guttata	1	6	6	0	0.5	0	0
Chelydra serpentina	0	7	3	0	0	0	0
Trachemys scripta	1	0	6	0	0	0	0
Anolis carolinensis	0	1	0	0	0	0	0
Eumeces fasciatus	2	10	7	0	2	0	0
Agkistrodon contortix	1	0	0	0	0	0	0
Agkistrodon piscivorus	8	1	0	0	1	0	0

Nerodia erythrogaster	1	0	1	0	2.5	0	0
Nerodia taxispilota	0	0	0	0	0	0	0
Nerodia fasciata	0	0	1	0	0.5	0	0
Storeria dekayi	0	1	0	2	0	0	0
Carphophis amoenus	0	0	0	1	0.5	0	0
Coluber constrictor	0	0	0	0	0.5	0	0
Diadophis punctatus	0	0	0	12	3.5	0	0
Farancia abacura	0	0	1	0	0.5	0	0
Elaphe obsoleta	1	0	0	0	0	0	0

Table 3. Habitat characteristics of Edisto River swamp, South Carolina, 1993. Values in the same row with the same letter were not significantly different at 5% alpha level.

	Clearcut		Edge		Control	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Over/midstory % cover	6a	1.9	74b	7.1	95c	0.5
Understory % cover	95a	1.0	48b	7.7	5c	1.4
Rotten coarse woody debris (m^2 cross-sectional area per 15-m transect)	3.3a	1.62	0.9a	0.41	2.6a	1.81
Sound coarse woody debris (m^2 cross-sectional area per 15-m transect)	8.1a	1.35	1.9b	0.41	1.1b	0.47
Soil surface temperature (C)	31.2a	4.2	No data		27.9a	0.8
Soil density (g/cm^3)	0.59a	0.02	No data		0.67a	0.05

are a forest wetland species, whereas leopard frogs are more ubiquitous (Mount 1975). Enge and Marion (1986) found fewer southern leopard frogs in clearcuts than in control areas in southern pine flatwoods.

Eastern narrowmouth toads emerge from burrows only when ground water is sufficiently pooled for breeding. Reduced evapotranspiration in the clearcut (Perison et al. 1993) may have increased the likelihood of these frogs receiving the cue to emerge. Skidder tire ruts may have had a similar effect on these and the other frog species, as they were a source of fish-free breeding pools (Phelps 1993).

Two species of treefrogs were captured, and these showed opposing preferences. Green treefrogs may have predominated in the clearcut because the traps (treefrog pipes) were level with their habitat (leafy sprouting vegetation). Green treefrogs may have been equally abundant in the control (as suggested by the number of control captures, Table 2), but may have been living higher than the traps were sampling. Gray treefrogs were rarely captured, and the reason again may have been that the traps were too low. The removal of trees in the clearcut may have excluded gray treefrogs because their habitat (tree boles) was removed. In the case of the green treefrogs in the clearcut, their habitat quickly returned, but at a lower height. Overall, the treefrog pipe method showed promise, as it was inexpensive and trapped significant numbers of frogs while causing them no apparent stress.

Reptiles may have preferred the clearcut because of increased temperature and insolation. A basking reptile would be at an advantage in the direct sun of the clearcut because it could achieve active temperatures faster and remain active longer through the day. Bury and Corn (1988), working in the Pacific Northwest, found that "reptiles predominate in clearcuts, most likely responding to increased ambient temperatures in such areas." The presence of a large amount of slash in the clearcut may have provided a valuable habitat component in the form of cover for reptiles or their prey. Reptiles that seemed to prefer the control included ringneck snakes (*Diadophis punctatus*), copperheads (*Agkistrodon contortix*), common musk turtles, and eastern box turtles. The reasons for these preferences are not clear, although ringneck snakes were the smallest and most fossorial reptile species regularly captured, and may have been less dependent on basking and more dependent on an undisturbed forest floor.

Recommendations and Conclusions

Clearcut size is one factor to be considered when planning for natural forest regeneration in forested wetlands. Amphibians and reptiles have relatively small home range sizes (Duellman and Trueb 1986) and, therefore, cannot disperse from or quickly recolonize impacted areas. Hairston (1987) found that salamanders return to their home range even after disturbance and handling. Small clearcuts with undisturbed sources of recolonization nearby were advocated by Buhlmann et al. (1988) and Enge and Marion (1986). A mosaic of small clearcuts, second growth, and undisturbed areas would likely create increased landscape diversity, as compared to a single homogeneous stand.

Recovery times of about 60 years for salamander populations in clearcut areas are given by Petranka et al. (1993) in the southern Appalachian and Pough et al. (1987) in New York. This suggests that long rotation times are needed to avoid a long-term decline of salamander populations over several rotations. Enge and Marion (1986) also recommended long rotation times that allow adequate recovery of herpetofaunal populations.

Controlling certain aspects of the harvest operation can minimize the adverse effects of a clearcut. Most importantly, snags and coarse woody debris should be left on the site (Enge and Marion 1986). Woody debris should be of large size and in an advanced state of decay (Bury and Corn 1988, Welsh and Lind 1988). Aubry et al. (1988) suggested that "the abundance levels of salamanders are more likely a function of the availability of woody debris for cover than age of the overstory." Since suitable woody debris is more abundant in older stands, longer rotation times are important. Leaf litter on the forest floor is another important component of herpetofaunal habitat (Pough et al. 1987, DeGraaf and Rudis 1990, Petranka et al. 1993), and can be destroyed by ground machinery such as skidders (Buhlmann et al. 1988). Skidders should be restricted to small areas, and helicopters should be used when practical. Buhlmann et al. (1988) recommended harvesting in the season of inactivity for the local herpetofauna, but some southern Coastal Plain species are active at all times of the year.

Further studies in which capture probabilities can be estimated would allow direct comparison of capture data among species in the same habitat, and within species across habitats. Remaining research opportunities include determining the fate of salamanders in the face of clearcutting, and monitoring subsequent recovery of populations through recolonization. Also, a study similar to ours, focusing on winter-active amphibians, would be valuable. In addition, the habitat value of skidder ruts should be studied. The possible benefit of extra standing water (Phelps 1993) may mitigate the effects of soil degradation (Buhlmann et al. 1988). Finally, additional work with PVC pipes for capturing treefrogs should be done, including their use in various habitats, with different species, and the possible effect of pipe height on trap efficiency.

The key to expanding knowledge in the area of wildlife habitat/forestry relationships is to replicate treatments. In this case, conclusions could have been strengthened by having several clearcuts and several control areas (Hurlbert 1984). Specific factors such as woody debris, size of clearcuts, and skidder rut impact could be studied with such a design. Ideally, each area would be sampled prior to the installation of the clearcut (Buhlmann et al. 1988). This would allow comparison of data from the clearcut before and after treatment, and from the control. Effects of space, time, and the treatment itself could be separated. Replication and the collection of baseline data could be achieved more easily within the framework of Adaptive Resource Management (Walters 1986). This is a system of research integrated with management, wherein management decisions are treated as hypotheses and tested with replicated trials. After several iterations of hypothesis and experiment, predictions involved with policy can become prescriptions based on hard data.

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